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**NOTE**

# EFFECTS OF NITROGEN AND CHLORMEQUAT ON GROWTH AND GRAIN YIELD OF WINTER BARLEY CULTIVAR 'VALFAJR'

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## ABSTRACT

A field experiment was conducted to investigate the effects of the growth regulator chlormequat (2-chloroethyl trimethyl ammonium chloride, CCC) and nitrogen as a top dressing fertilizer at three levels (0, 50 and 100 kg ha$^{-1}$) applied at the beginning of stem elongation, in addition to 18 kg N ha$^{-1}$ on seed bed, on growth and yield of winter barley (*Hordeum vulgare* L.). The results indicated that early application of CCC, i.e. application at glumme-lemma primordium stage of the main shoot, was associated with both increased fertile shoots per plant and grain number per spike and although the mean kernel weight of the CCC-treated plants was lower than controls, it was over-compensated for by increased grain number per

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plant, so that the grain yield was increased by CCC-treatment. Application of nitrogen also increased associated grain production and the grain yield at 50 and 100 kg N $ha^{-1}$ levels. The highest grain yield was obtained from plots which received early application of CCC with 50 kg N $ha^{-1}$. The interactive effect of CCC and nitrogen under the varying agroclimatic conditions of Iran is worthy of further exploration.

**تحقیقات کشاورزی ایران**

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# تاثیر نیتروژن و کلرمکوات کلرید بر رشد و عملکرد دانــه جـو پائــیزه رقم 'والفجر'

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به ترتیب دانشیار بخش زراعت و اصلاح نباتات دانشکده کشاورزی دانشگاه شیراز، دانشجوی سابق کارشناسی ارشد و دانشیار گروه زراعت و اصلاح نباتات دانشکده کشاورزی دانشگاه تهران، ایران.

## چکیده

در یک آزمایش مزرعه ای تاثیر کـاربرد کـلرمکوات کـلرید (۲-کـلرواتیل تـری متیـل آمونیـوم کلرید، CCC ) و نیتروژن از منبع اوره به صورت سرک (در شروع رشد طولی سـاقه) در سه سـطح ۰، ۵۰ و ۱۰۰ کیلو گرم در هکتار، علاوه بر ۱۸ کیلوگرم نیتروژن در هکتار که در ابتدای آزمایش به همه کرتها داده شد، بررشد و عملکرد دانه جو پاییزه رقم 'والفجر' مورد بررسی قرار گرفت. نتایج به‌دست آمده نشان داد که کاربرد به موقع CCC، یعنی مصرف در زمان انگیزش آغازه های گلـوم و

لما در سنبله اولیه ساقه اصلی، با افزایش تعداد ساقه های بارور در هربوته و افزایش تعداد دانه در هر سنبله همراه بود و اگر چه میانگین وزن دانه در تیمارCCC، کمتر از شاهد بود ولی افزایش تعداد دانه نه تنها این کاهش را جبران نمود بلکه موجب افزایش معنی دار عملکرد دانه در تیمارCCC نسبت به شاهد گردید. کاربرد نیتروژن در سطوح ۵۰ و۱۰۰ کیلو گرم در هکتار باعث افزایش معنی دار عملکرد دانه گردید و بیشترین عملکرد دانه از تیمار CCC همراه با کاربرد۵۰ کیلو گرم نیتروژن در هکتار بصورت سرک بدست آمد. درک برهمکنش نیتروژن و CCC در شرایط اقلیمی گوناگون ایران نیازمند مطالعه و بررسی های بیشتری است.

## INTRODUCTION

The breeding of barley cultivars with such improved characteristics as shorter and stronger straw seems very costly in termsof time and resources. However, appropriate use of growth retardants such as chlormequat (2-chloroethyl-trimethyl ammonium chloride, CCC) might be considered as an alternative approach. Stem elongation is a plant response to increased levels of endogenous gibberellins (GAs) and growth retardants can interfere with GA biosynthesis and shorten the basal internodes of cereal culms (10, 22). Of the many chemical species screened for the anti-GA activity, chlormequat chloride is the most widely used in agricultural production, since the results are relatively consistent and the chemical is not expensive (3, 7, 15). However, there are many lines of evidence indicating that a timely application of a retardant such as chlormequat chloride could increase yield of both wheat and barley, independently of any control of lodging (e.g., 3, 11, 16). Also, timely application of nitrogen fertilizers has been shown to increase tiller density and/or tiller fertility (e.g., 18). Consequently, increased nitrogen application within the full range of normal experimental rates (i.e. 0-200 kg N $ha^{-1}$) gives increased ear population density (e.g., 23). The nitrogen requirement of wheat and barley rises sharply just before the beginning of rapid stem elongation growth i.e., at Zadoks Growth Stage

(ZGS) 30. (24). Moreover, it has been shown that tiller mortality has been reduced following timely application of nitrogen, i.e., application at the beginning of the most rapid phase of crop growth, when intra-plant competition for nitrogen is at its greatest (9).

The aim of the present investigation was to examine the effect of top dressing nitrogen at the most critical stage of plant growth with or without timely application of CCC, on growth and yield of the widely grown winter barley cultivar 'Valfajr' under the agroclimatic conditions of the central part of Iran.

## MATERIALS AND METHODS

In a field experiment conducted at the Experimental Farm of College of Agriculture, Tehran University, Karaj, Iran (35°48'N and 50°57' E), graded seeds (3-3.25 mm) of the two-rowed winter barley cultivar 'Valfajr' were hand-sown on 12 November 1995 to give the exact density of 300 plants $m^{-2}$. Uniformity of sowing depth was achieved by using a hand dibber and perforated plywood sheets. Seedlings which failed to emerge were quickly replaced with matched spares (raised in individual containers) to obtain the exact density. The design of the experiment was a split plot with four replicates. Nitrogen levels (0, 50 and 100 kg $ha^{-1}$) formed the main plots and CCC treatments (with or without) were the subplots. A seed bed application of nitrogen and phosphorus was achieved for all plots at the rate of 150 kg $ha^{-1}$ ammonium phosphate . No herbicide was necessary since the plots (5×2 m) were regularly hand weeded. At ZGS 30 (24), i.e., 130 days after sowing (DAS) the top dressing of nitrogen at the rates of 0, 50 and 100 kg N $ha^{-1}$ was achieved by using ammonium nitrate (34.5 % N). The CCC treatment was applied as "Arotex Extra" at ca. 1610 g $ha^{-1}$ with a precision sprayer (pressure 3 bar). Rigid screens were used to prevent spray drift. The CCC was applied at the double ridge stage of the main shoot (DS=2.0 according to Waddington scale (20), when the ear initial was about 1.5 mm long and the true stem length was about 7-10 mm. No elongated nodes were detectable and tillering was underway.

During the growing season, areas of 25×5 cm were frequently harvested to record the short and long term effects of treatments on both growth and development. Within each subplot, an area of 200 × 100cm (with guard rows) was marked and left undisturbed for harvesting at crop maturity. On this final harvest sample, phytomass production was measured and yield component analysis was carried out. Dry weights were recorded after the plant material had been oven-dried at 80°C for 48 hr. The data were analyzed by analysis of variance and the means compared by Duncan's test.

## RESULTS AND DISCUSSION

### Effects of Nitrogen and CCC on the Vegetative Phase of Barley Development

Top dressing of nitrogen was associated with greater tiller production so that at peak tillering (i.e., ZGS 32) the number of tillers per plant were 2.7, 3.3 and 3.5 for 0, 50 and 100 kg N $ha^{-1}$, respectively (Table 1). Such response of tillering to nitrogen top dressing was maintained until anthesis, so that the numbers of fertile shoots per plant at flowering were 1.1, 1.4 and 1.5 for 0, 50 and 100 kg N $ha^{-1}$, respectively (Table 1). Increases in tiller number and/or fertile shoots per plant found in this study confirmed the results obtained by others (e.g., 2, 5). Indeed, the N applied at the beginning of stem elongation promoted the survival of tillers which as has been previously shown by Gallagher *et al.* (5), would otherwise die at this stage.

The short term responses to early application of CCC (i.e., application at the double ridge stage of the main shoot) included retardation of development of the treated plants and also retardation of shoot elongation and leaf area expansion (Tables 2 and 3). This retardation of growth was also associated with smaller dry matter accumulation (Table 3). However, this trend was reversed before anthesis so that by anthesis, that is when the number of fertile shoots per plant was fixed, the CCC-treated plants had higher leaf area indices and greater dry matter accumulation (Table 1). CCC

Table 1. Effect of CCC and nitrogen on number of tillers per plant, leaf area index and dry matter accumulation .

| DAT[†] | kg N ha$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 50 | | 100 | |
| | -CCC | +CCC | -CCC | +CCC | -CCC | +CCC |
| | **Tillers plant $^{-1}$** | | | | | |
| 0 | 1.14a[§] | 1.12a | 1.11a | 1.11a | 1.12a | 1.11a |
| 7 | 1.21d | 1.30cd | 1.33cd | 1.59ab | 1.38bc | 1.65a |
| 14 | 1.69c | 1.83d c | 1.96 d | 2.22ab | 2.04cd | 2.31a |
| 21 | 2.15de | 2.33cd | 2.6bc | 2.84b | 2.68bc | 2.96a |
| 28 | 2.6if | 2:81e | 3.2de | 3.45b | 3.32c | 3.58a |
| 35 | 1.99e | 2.12d | 2.44c | 2.63ab | 2.53bc | 2.74a |
| 42 | 1.42e | 1.51d | 1.74c | 1.87b | 1.80bc | 1.95a |
| 49 | 1.02e | 1.32cd | 1.27 d | 1.63b | 1.33c | 1.70a |
| | **Leaf area index** | | | | | |
| 0 | 0.45a | 0.45a | 0.44a | 0.45a | 0.46a | 0.46a |
| 6 | 0.84bc | 0.80c | 0.89ab | 0.84bc | 0.94a | 0.90a |
| 17 | 1.1bc | 1.05c | 1.20a | 1.10bc | 1.22a | 1.12ab |
| 28 | 2.41d | 2.89b | 2.60c | 3.05ab | 2.70c | 3.1a |
| 39 | 444e | 4.74d | 4.69d | 4.99b | 4.88c | 5.05a |
| 50 | 5.61e | 6.15f | 5.93cd | 6.49ab | 6.18c | 6.56a |
| 61 | 5.22f | 5.47de | 5.51d | 5.78b | 5.75bc | 5.84a |
| | **Dry matter accumulation ( g m$^{-2}$)** | | | | | |
| 0 | 18.1a | 17.8bc | 17.8ab | 18.0a | 17.9ab | 17.5c |
| 6 | 45.9b | 30.0d | 49.8a | 308cd | 50.3a | 31.1cd |
| 17 | 62.9b | 46.2e | 65.5ab | 48.0de | 66.5a | 50.6c |
| 28 | 193.7cd | 197.0cd | 198.0bc | 205.1b | 200.5bc | 214.0a |
| 39 | 477.0d | 573.6b | 489.4cd | 576.0b | 501.8c | 601.5a |
| 50 | 962.9cd | 1047.1bc | 990.8c | 1100.0b | 1007.7c | 1153.1a |
| 61 | 1206.9ef | 1326.8c | 1237.7de | 1388.1a | 1245.9de | 1394.1a |

† Days after treatment.

§ Means followed by the same letter in each row are not significantly different at $P \leq 0.05$.

Table 2. Phenology of winter barley cultivar 'Valfajr' treated with chlormequat chloride (+CCC ) or untreated (-CCC ).

| Growth stage | ZGS† | Days after sowing -CCC | Days after sowing +CCC |
|---|---|---|---|
| Beginning of stem elongation | 30 | 143 | 146 |
| Rapid stem elongation | 32 | 159 | 163 |
| Booting | 45 | 168 | 171 |
| Awns visible | 49 | 171 | 173 |
| Ear emergence | 55 | 175 | 177 |
| Anthesis | 61 | 180 | 181 |
| Ripening | 95 | 215 | 217 |

† Zadoks growth stage ( 24 ).

Table 3. Short term effects of application of CCC ( day 21 ) under different nitrogen top dressing on growth of barley plants.

| Growth regulator | Top dressed nitrogen ( kg ha$^{-1}$ ) 0 | 50 | 100 |
|---|---|---|---|
| | | True stem length ( mm ) | |
| -CCC | 18.21 | 20.32 | 22.46 |
| +CCC | 11.46† | 12.25† | 13.24† |
| | | Leaf area index | |
| -CCC | 1.10 | 1.20 | 1.25 |
| +CCC | 1.05 | 1.10† | 1.12† |
| | | Dry weight ( gm$^{-2}$ ) | |
| -CCC | 62.80 | 65.51 | 66.53 |
| +CCC | 46.20† | 48.11† | 50.60† |

† Significant at 5 % level.

also enhanced tillering and by ZGS 32 (i.e. peak tillering) the number of shoots per plant was higher in CCC-treated plants and this trend was carried through until anthesis (Table 1). The results of the present study also indicated that sink size could be manipulated during the early reproductive phase, i.e., when a small reduction in the rate of spike development, and therefore stem elongation in the leading shoots results in greater within-plant shoot uniformity giving a higher rate of tiller survival. These findings are consistent with the results reported by other researchers (e.g., 3, 8, 12, 13, 14).

## Effects of Nitrogen and CCC on Grain Yield and its Components

Among the N levels, the highest grain yield was obtained from plots top dressed with 100 kg N $ha^{-1}$ (Table 4). The higher grain yield was the result of a higher grain number which in turn was due to more fertile shoots $m^{-2}$. Such higher grain yield was also associated with both higher biological yield and increased harvest index (Table 4).

Table 4 . Effect of CCC on grain yield and its components under different nitrogen top dressing conditions.

| Yield and yield components | | Nitrogen levels (kg $ha^{-1}$) | | |
|---|---|---|---|---|
| | | 0 | 50 | 100 |
| Grain yield (g $m^{-2}$ ) | -CCC | 597.18 | 642.57 | 647.10 |
| | +CCC | 690.55† | 773.68 | 764.88 |
| Grain number ($m^{-2}$ ) | -CCC | 15612.00 | 17421.00 | 17824.00 |
| | +CCC | 18539.00† | 21150.00† | 21837.00† |
| Ear number ($m^{-2}$ ) | -CCC | 607.25 | 680.50 | 699.00 |
| | +CCC | 697.75† | 788.00† | 805.50† |
| Mean kernel weight (mg ) | -CCC | 38.25 | 36.90 | 36.30 |
| | +CCC | 37.25† | 36.60 | 35.00† |
| Biological yield ( g $m^{-2}$ ) | -CCC | 1457.60 | 14494.80 | 504.10 |
| | +CCC | 1723.10† | 1802.70† | 1836.10† |
| Harvest index (% ) | -CCC | 40.97 | 43.00 | 43.02 |
| | +CCC | 40.08 | 42.92 | 41.66† |

† Significantly different from the corresponding control at 5% level.

In the plots which received no top dressed nitrogen, the number of fertile shoots was lower, while the mean kernel weight was greater (Table 4). Similar results were reported by Easson (2). Promotion of tillering and increase in fertile shoots per plant following spring application of nitrogen have also been reported by Frederick and Camberato (4) and Ramos *et al.* (17).

Chlormequat chloride increased the grain yield of barley plants at all nitrogen levels. However the highest grain yield was obtained from plots which received CCC and 50 kg N $ha^{-1}$ (Table 4). This yield increase was the result of increase in grain number. Although the mean kernel weight of the CCC-treated plots was lower than untreated controls (Table 4), it was over-compensated for by increased grain number. Increase in grain number was in turn due to increased ear number per unit area (Table 4). The increased grain yield in CCC-treated plots was also associated with a significant increase in biological yield at all nitrogen levels with no significant effect on harvest index, except for the 100 kg N $ha^{-1}$ treatment (Table 4).

The increased sink size due to early application of CCC was associated with a proportional increase in phytomass production, confirming the results reported by others (e.g. 3, 19). Indeed, such higher phytomass production later, in pre-anthesis and during the post-anthesis period, seems to be an important part of the response to CCC and this could be achieved only when the conditions for crop photosynthesis are favorable.

That the feedback effect of a larger sink on the source leads to an increase in phytomass accumulation is consistent with the findings of Waddington *et al.* (21) and Austin *et al.* (1) who reported that improved grain yield in "modern" (i.e., after 1980) wheat genotypes was associated with the production of more biomass compared with the new high yielding "Green Revolution" varieties of 1960's and 1970's. Also, Austin *et al.* (1) comparing old (i.e., pre 1960) and modern (i.e., since 1980) cultivars concluded that under favorable conditions, the modern cultivars generally outyielded the older ones because of their greater biomass production while maintaining the high harvest index levels of the 1960's-1980's. Thus, the genetic variation in capacity to produce more biomass could only be expressed in favorable years when it can be considered to benefit yield. This is probably why there are conflicting reports on yield increase following application of CCC (e.g., 6). Further investigations may shed more light on potential ability of CCC to increase grain yield in wheat and barley under different agroclimatic conditions of Iran.

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